PATENT SPECIFICATION

686,383

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COMPLETE SPECIFICATION.

Improvements in or relating to Gas-Turbine Engines.

We, ROLLS-ROYCE LIMITED, a British Company, of Nightingale Road, Derby, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement :—

This invention relates to gas-turbine engines and is concerned more particularly with combustion equipment for such engines.

One well-known form of combustion equipment comprises a plurality of separate combustion chambers disposed in a ring about a shaft interconnecting an engine compressor with an engine turbine, each combustion chamber comprising a tubular air casing with a substantially coaxial flame tube located within the air casing in spaced relation thereto; in such a construction the combustion of the fuel occurs within the flame tube and the air entering the combustion chamber flows partly into the flame tube at its inlet end (that is the end adjacent the inlet of the combustion chamber) and partly around the outside of the flame tube between it and the air casing to enter the flame tube at points along its length.

A second well-known form of combustion equipment comprises an annular combustion chamber formed by inner and outer air casing walls which encircle a shaft interconnecting a compressor and turbine and a plurality of flame-tubes disposed within the annular space between the air casing walls; in this construction also the air entering the flame tubes flows partly through their inlet ends and partly around the outside thereof in the spaces between the flame tubes and the air casing walls to enter the flame tubes at points along their length, the fuel being burnt within the flame tubes.

A third well-known form of combustion equipment comprises an annular combustion chamber formed by inner and outer air casing walls which encircle a shaft interconnecting a compressor and turbine, and a substantially coaxial annular flame tube disposed within the annular space between the air casing walls and in spaced relation thereto; in this construction also the air entering the flame tube flows partly through its inlet end and partly into the annular spaces between the flame tube and the air casing walls to enter the flame tube at points along its length, the fuel being burnt within the flame tube.

In each of these constructions, the inlet end of a combustion chamber is normally a chamber (hereinafter referred to as an expansion chamber) of increasing cross-sectional area in the direction of flow of gas through it, and the separation of the air flowing directly into a flame tube and the air flowing outside it is normally effected in the expansion chamber. Hitherto, such separation has been effected by an integral part of the flame tube.

According to this invention, there is provided in combustion equipment comprising a flame tube located within and spaced from an air casing, means to separate air entering the flame tube at its inlet end from air flowing around the outside of the flame tube comprising a duct part, made in one piece, of which one edge divides the air flow and which is supported from the wall of the expansion chamber portion of the air casing by one or more struts extending from the duct part to a point of connection with the expansion chamber wall, and which is arranged to afford at its outlet end a support for the inlet end of the flame tube. Preferably the strut or struts are made integral with the duct part, and preferably the duct part affords a passage therethrough which diverges from its inlet end to its outlet end.

In the arrangement of this invention,

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therefore, the means to separate the air entering the flame tube at its inlet end from air flowing round the outside thereof is separate from the flame tube, the latter being removable independently thereof.

According to a feature of the invention, the strut, or some or all of the struts may have an extension to within the diverging passage through the duct part and may terminate in a boss for supporting a fuel injection nozzle, the fuel feed ducts to the nozzle being formed in a strut or struts.

According to yet another feature of this invention, the duct part may be arranged to support the inlet end of the flame tube by having a part at least of the periphery of its outlet end formed as a seat with which the inlet of the flame tube is engaged.

In constructions of combustion equipment comprising a plurality of separate air-casings housing individual flame tubes, the duct part will normally be frusto-conical and the periphery of the larger end of the duct part may conveniently be arranged to support the inlet end of the flame tube by being formed at its outlet end with a cylindrical flange which fits into the inlet to the flame tube.

In constructions of combustion equipment comprising a plurality of flame tubes in an annular chamber a similar duct part may be employed.

In constructions of combustion equipment comprising an annular flame tube between co-axial annular air casing walls, the air separating means may comprise a plurality of duct parts each having the form of a sector of an annulus (or "pillar-box" slot form) and together forming an annularly extending duct, and the flame tube may be supported by engaging its inlet end over the radially inner and outer peripheral portions of the duct parts at least. Each of the sector duct parts is made in one piece, and its leading edge divides the air flow. Conveniently each of the sector duct parts is supported from the wall of the expansion chamber by a single strut. Two or more injection nozzles may be associated with each sector duct part and a plurality of the sector duct parts may be employed to form a substantially annular assembly.

In some constructions according to the invention, the duct part may be formed internally with a liner so that a desired internal profile may be obtained independently of the external profile of the duct part. The liner will preferably be formed of sheet metal to save weight.

Three constructions of combustion equipment for gas-turbine engines embodying this invention will now be described by way of example, the description making reference to the accompanying drawings in which :—

Figure 1 is a view of the inlet end of one form of combustion chamber with parts in section ;

Figure 1A is a view on a larger scale of a part of Figure 1 ;

Figures 2 and 3 are sections on the lines 2—2 and 3—3 respectively of Figure 1 ;

Figure 4 is a view corresponding to Figure 1 of a second construction of combustion chamber ;

Figures 5 and 6 are sections on the lines 5—5 and 6—6 of Figure 4 ;

Figure 7 is a view corresponding to Figure 1 of a third construction of combustion equipment ;

Figure 8 is a section on the line 8—8 of Figure 7 ; and

Figure 9 is a section on the line 9—9 of Figure 8.

In the first embodiment illustrated in Figures 1 to 3, the combustion equipment for the gas-turbine engine comprises a plurality of combustion chambers of which only one is shown.

Each combustion chamber consists of an air casing 10 with a flame tube 11 mounted centrally within the air casing 10 so that the air entering the combustion chamber, say from a compressor delivery 12, is divided into two streams, one entering the flame tube at its mouth 11*a* and the other flowing around the outside of the flame tube 11 in the annular space 13 between the flame tube 11 and air casing 10 to enter the flame tube through apertures or passages in the wall thereof.

In this construction, as is usual, the inlet end of the air casing is formed as an expansion chamber 10*a*.

The flame tube 11, which is manufactured from sheet metal, has its inlet end located downstream from the inlet end of the expansion chamber 10*a* and the mouth 11*a* of the flame tube 11 is bounded by an axially-extending cylindrical flange 14 formed by turning the metal bounding the mouth of the flame tube back upon itself. A short sleeve 14*a* may be welded to the flange 14 internally thereof to provide a bearing surface.

In accordance with this invention, means is provided which separates the air entering the combustion chamber into two streams, one of which passes into the flame tube 11 through the mouth 11*a* thereof and the other of which streams flows around the flame tube 11 to enter it through apertures or passages in its walls.

In this construction the means comprises a frusto-conical duct part 15 which is located within the expansion chamber 10*a* and extends from adjacent the inlet end of the air casing to the plane of the mouth 11*a* of the flame tube 11, the duct part 15 having its narrower end adjacent the inlet to the air casing. The duct part has formed integrally with it three equi-angularly disposed radial strut-like parts 16 by which the duct part is

connected with the air casing. These strut-like parts extend radially from the outer surface of the duct part 15 to terminate in feet 17 which engage within recesses of blister-like features 18 in the wall of the expansion chamber 10*a* and the strut-like parts are secured to the expansion chamber by these feet 17.

Each strut-like part 16 has an extension 16*a* projecting radially inwards from the duct part 15 to a central boss 19 which supports a fuel injection device 20 and the fuel supply to the fuel injection device 20 is led through ducts 21 running through the strut-like parts 16, 16*a* from the feet 17 thereof. Conveniently the feet 17 are provided with threaded sockets which receive union plugs 22 and the union plugs 22 extend through the walls of the blister-like features 18 to secure the feet 17 to the walls of the expansion chamber 10*a*.

The larger end of the frusto-conical duct part 15 is formed externally with a cylindrical seat 23 to engage within the sleeve 14*a* secured to the flange 14 bounding the mouth 11*a* of the flame tube 11, so that, when the duct part 15 is located in position, the inlet end of the flame tube can be supported by the short sleeve 14*a* engaging on the cylindrical seat 23. The duct part 15 is also preferably formed with a shoulder 24 to limit the extent of axial movement of the flame tube 11 in the upstream direction when it is engaged with the cylindrical seat 23.

Referring now to Figures 4 to 6, there is illustrated a second construction of combustion equipment which is of the type comprising an annular combustion chamber having an inner annular wall 30 and an outer annular wall 31 and a plurality of tubular flame tubes, such as the flame tubes 11 of the arrangement of Figures 1 to 3, disposed in a ring within the space between the inner and outer air casing walls 30, 31. As will be seen from Figure 4, the inner and outer walls 30, 31 are connected with a compressed air delivery section 32 and they diverge away from one another at their inlet end to form an expansion chamber.

As in the construction of Figures 1 to 3, the mouths 11*a* of the flame tubes 11 are located downstream of the inlet end of the expansion chamber, and there is provided for each flame tube 11, means to divide the air entering the expansion chamber into two streams, one of which enters the flame tube 11 through the mouth 11*a* thereof and the other of which flows into the spaces between the flame tubes 11 and the inner and outer air casing walls 30 and 31 and enters the flame tubes through apertures in the walls thereof.

The means for dividing the air flow into two streams is of similar construction to that illustrated in Figures 1 to 3, and comprises the frusto-conical duct part 15 with a cylindrical seat 23 to be engaged by the flange 14 around the mouth of the flame tube 11 and the shoulder 24 to limit the axial extent of engagement of the flame tube 11 on the seat 23.

In this construction, the duct part 15 is supported from the outer air casing wall 31 by means of a single strut-like member 33 extending outwardly from the external surface of the duct part 15 and having at its outer end an axially elongated foot 34 which engages within a recess in a cap 35 occupying an elongated aperture in the outer air casing wall 31, which aperture is bounded by an upstanding land 36 affording a seat for a bolting flange 35*a* on the cap 35. The cap 35 is secured to the land 36 by means of studs 37 extending through the flange 35*a*, and the foot 34 of the strut-like member 33 is secured to the cap 35 by means of studs 38. The bottom of the recess for receiving the foot 34 is cut away to receive a pair of union plugs 39 communicating with ducts 40 running through the strut-like member 33. The elongated aperture in the outer air casing wall 31 may, if desired, be made of sufficient size for the duct part 15 to be withdrawn through it.

The strut-like member has a radial extension 33*a* within the duct part 15 and the extension 33*a* terminates in a boss 41 carrying a fuel injection device 42. The ducts 40 also run through the extension 33*a* of the strut-like member 33 and the boss 41 and lead to the fuel injection device 42.

Referring now to Figures 7 to 9, there is illustrated a form of combustion equipment comprising an annular combustion chamber having coaxial inner and outer air casing walls 50, 51 respectively and within the annular spaces between the walls 50, 51 a coaxially arranged annular flame tube having an inner wall 52 and an outer wall 53 affording between them a fuel combustion space.

As in the previous construction, there is provided in the expansion chamber portion of the combustion equipment means to divide the air entering the expansion chamber from delivery duct 54 essentially into two streams, one of which enters directly into the flame tube through its mouth 55 and the other of which passes into the annular space 56 between the inner air casing wall 50 and the inner flame tube wall 52 and the annular space 57 between the outer air casing wall 51 and the outer flame tube wall 53 to flow through these spaces 56 and 57 and to enter the flame tube through apertures in the walls 52, 53 thereof.

The means for dividing the air into these streams comprises essentially an annular duct of divergent cross-section and in the construction illustrated the annular duct is formed in a number of duct parts 58 each of which has a cross-section at right angles to

the axis of the flame tube which is a sector of an annulus. Each duct part 58 has formed integrally with it a strut-like member 59 having a foot at its radially outer end 60 to engage in a blister-like feature 61 on the outer air casing wall 51. Bolts 62 are provided to secure the feet 60 in position within the blister-like feature 61. The radially-outer wall 58*a* of each duct part 58 is formed with an axial flange 63 and the axial flanges 63 together form an annular seat which spigots within the mouth of the outer flame tube wall 53. The radially-inner wall 58*b* of each duct section is also provided with an axial flange 64 which axial flanges 64 together form an annular seat over which engages the mouth of the flame tube inner wall 52. In this way the walls 52, 53 of the flame tube are located at their inlet ends with respect to the air casing walls 50, 51.

The inner and outer air casing walls 50, 51 may conveniently be interconnected by radial webs 65 and these radial webs may be formed with axially-extending bosses 66 carrying on their downstream ends fuel injection devices 67.

In the arrangement illustrated there is provided a radial web 65 and an associated fuel injection device 67 for each pillar-box slot-like duct part 58, and the fuel injection device 67 is located essentially within the pillar-box slot. If desired, however, more than one fuel injection device may be provided for each pillar-box slot.

Fuel is fed to the fuel-injection devices 67 through ducts 68 extending through the radial webs 65 and axial bosses 66.

If desired the strut-like members 59 may be made in two parts, of which one part is formed integral with the outer air casing wall 51 and the other part is made integral with the annular duct part 58, the two parts abutting one another and being secured together to locate the duct part 58 within the expansion chamber.

What we claim is :—

1. Combustion equipment for gas-turbine engines of the kind comprising a flame tube located within and spaced from an air casing, characterised in that there is provided means to separate air entering the flame tube at its inlet end from air flowing around the outside of the flame tube comprising a duct part, made in one piece, of which one edge divides the air flow and which is supported from the wall of the expansion chamber portion of the air casing by one or more struts extending from the duct part to a point of connection with the expansion chamber wall, and which is arranged to afford at its outlet end a support for the inlet end of the flame tube.

2. Combustion equipment as claimed in Claim 1, characterised in that the strut or struts are made integral with the duct part.

3. Combustion equipment as claimed in Claims 1 or 2, in which the duct part affords a passage diverging from its inlet end to its outlet end.

4. Combustion equipment as claimed in Claim 3, wherein one strut at least has an extension to within the divergent passage through the duct part and terminates in a boss supporting a fuel-injection nozzle, there being fuel feed ducts to the fuel-injection nozzle formed in the strut.

5. Combustion equipment according to any of Claims 1 to 4, characterised in that the duct part is arranged to support the inlet end of the flame tube by having a part at least of the periphery of its outlet end formed as a seat with which the inlet of the flame tube is engaged.

6. Combustion equipment as claimed in any of Claims 1 to 5, having a plurality of flame tubes accommodated in individual air casings or in a single air casing, characterised in that the duct part associated with each flame tube is frusto-conical and the periphery of the larger end of the duct part is arranged to support the inlet end of the flame tube by being formed at its outlet end with a cylindrical flange which fits into the inlet of the flame tube.

7. Combustion equipment as claimed in any of Claims 1 to 5, having an annular flame tube between coaxial annular air casing walls, characterised by the provision of a plurality of duct parts each of pillar-box slot form and together affording a substantially annular duct part and characterised by the flame tube being supported by having its inlet end engaged over the radially-inner and radially-outer peripheral portions of the pillar-box slot duct parts.

8. Combustion equipment as claimed in Claim 7, characterised by the provision of two or more injection nozzles for each pillar-box slot duct part.

9. Combustion equipment for gas-turbine engines substantially as hereinbefore described with reference to and as illustrated in Figures 1 to 3, or Figures 4 to 6, or Figures 7 to 9 of the accompanying drawings.

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PROVISIONAL SPECIFICATION.

Improvements in or relating to Gas-Turbine Engines.

We, ROLLS-ROYCE LIMITED, a British Company, of, Nightingale Road, Derby, do hereby declare the nature of this invention to be as follows :—

This invention relates to gas-turbine engines and is concerned more particularly with combustion equipment for such engines.

On well-known form of combustion equipment comprises a plurality of separate combustion chambers disposed in a ring about a shaft interconnecting an engine compressor with an engine turbine, each combustion chamber comprising a tubular air casing with a substantially coaxial flame tube located within the air casing in spaced relation thereto ; in such a construction the combustion of the fuel occurs within the flame tube and the air entering the combustion chamber flows partly into the flame tube at its inlet end and partly around the outside of the flame tube between it and the air casing to enter the flame tube at points along its length.

A second well-known form of combustion equipment comprises an annular combustion chamber which encircles a shaft interconnecting a compressor and turbine and a plurality of flame-tubes disposed within the annular combustion space ; in this construction also the air enters the flame tubes partly through their inlet ends and partly flows around the outside thereof to enter the flame tubes at points along their length, the fuel being burnt within the flame tubes.

A third well-known form of combustion equipment comprises an annular combustion chamber which encircles a shaft interconnecting a compressor and turbine and an annular flame tube disposed within the annular combustion chamber and in spaced relation thereto ; in this construction also the air enters the flame tube partly through its inlet end and partly flows into the annular spaces between the flame tube and the walls of the combustion chamber to enter the flame tube at points along its length, the fuel being burnt within the flame tube.

In each of these constructions, the inlet end of a combustion chamber is normally a chamber of increasing cross-section in the direction of flow, hereinafter referred to as an expansion chamber, and the separation of the air flowing directly into a flame tube and the air flowing outside it is normally effected in the expansion chamber. Hitherto, such separation has been effected by a part formed integrally with the flame tube.

According to this invention, there is provided in combustion equipment comprising a flame tube located within and spaced from an air casing, means to separate air entering the flame tube at its inlet end from air flowing around the outside of the flame tube comprising a divergent duct part which is supported from the expansion chamber portion of the air casing by one or more struts extending from the duct part to a point of connection with the expansion chamber portion of the air casing, which means diverges from its inlet end to outlet end and which is arranged to provide a support for the inlet end of the flame tube. Preferably the strut or struts are made integral with the duct part.

It will be appreciated that the means to separate the air entering the flame tube at its inlet end from air flowing round the outside thereof is separate from the flame tube, the latter being removable independently thereof.

According to a feature of the invention, the strut, or some or all of the struts may have an extension to within the duct part and may terminate in a boss for supporting a fuel injection nozzle, the fuel feed ducts to the nozzle being formed in a strut or struts.

According to yet another feature of this invention, the duct part may be arranged to support the inlet end of the flame tube by having a part at least of the periphery of its outlet end formed as a seat with which the inlet of the flame tube is engaged.

In constructions of combustion equipment comprising a plurality of separate air-casings housing individual flame tubes, the duct part will normally be frusto-conical and the periphery of the larger end thereof may conveniently be arranged to support the inlet end of the flame tube by forming the outlet end with a cylindrical flange which fits into the inlet to the flame tube.

In constructions of combustion equipment comprising a plurality of flame tubes in an annular chamber a similar duct part may be employed.

In constructions of combustion equipment comprising an annular flame tube in an annular chamber, the duct part may be extended circumferentially to have a "pillar-box" slot form and the flame tube may be supported by engaging its inlet end over the radially inner and outer peripheral portions of the duct part at least. With the latter construction, two or more injection nozzles may be associated with each duct part and a plurality of the duct parts may be employed to form a substantially annular assembly.

In some constructions according to the invention, the duct part may be formed internally with a liner so that a desired internal

profile may be obtained independently of the external profile of the duct part. The liner will preferably be formed of sheet metal to save weight.

Three constructions of combustion equipment for gas-turbine engines embodying this invention will now be described by way of example.

In the first embodiment, the combustion equipment for the gas-turbine engine comprises a plurality of combustion chambers each consisting of an air casing with a flame tube mounted centrally within the air casing so that the air entering the combustion chamber is divided into two streams, one entering the flame tube at its mouth and the other flowing around the outside of the flame tube in the annular space between the flame tube and air casing to enter the flame tube through apertures or passages in the wall thereof.

In this construction, as is usual, the inlet end of the air casing is formed as an expansion chamber.

The flame tube, which is manufactured from sheet metal, has its inlet end located downstream from the inlet end of the air casing and the mouth of the flame tube is bounded by an axially-extending cylindrical flange formed by turning the metal bounding the mouth of the flame tube back upon itself. A short sleeve may be welded to the flange internally thereof to provide a bearing surface.

In accordance with this invention, means is provided which separates the air entering the combustion chamber into two streams, one of which passes into the flame tube through the mouth thereof and the other of which flows around the flame tube to enter it through apertures or passages in its walls. In this construction the means comprises a frusto-conical duct part which is located within the expansion chamber and extends from the inlet end of the air casing to the plane of the mouth of the flame tube, the duct part having its narrower end adjacent the inlet to the air casing. The duct part has formed integrally with it three equi-angularly disposed radial strut-like parts by which the duct part is connected with the air casing. These strut-like parts extend radially from the outer surface of the duct part to terminate in feet which engage within blister-like features in the wall of the air casing and the strut-like parts are secured to the air casing by these feet. Each strut-like part is also extended radially inwards from the duct part to a central boss which supports a fuel injection device and the fuel supply to the fuel injection device is led through ducts running through the strut-like parts from the feet thereof. Conveniently the feet are provided with threaded sockets which receive union plugs which extend through the walls of the blister-like features and provide the means whereby the strut-like parts are secured to the walls of the air casing.

The larger end of the frusto-conical duct part is formed externally with a cylindrical seat to engage within the sleeve secured to the flange bounding the mouth of the flame tube, so that, when the duct part is located in position, the inlet end of the flame tube can be supported by the short sleeve engaging on the cylindrical seat. The duct part is also preferably formed with a shoulder to limit the extent of axial movement of the flame tube in the upstream direction when it is engaged with the cylindrical seat.

The second construction of combustion equipment comprises an annular combustion chamber in which a plurality of flame tubes are disposed and in this construction there is provided for each flame tube a duct part for separating the air which is to flow directly into the flame tube from that which flows around it.

The combustion equipment, which is described in connection with British Patent Application No. 16955/49 (Serial No. 686,382) comprises an annular expansion chamber formed as a single casting with inner and outer combustion chamber walls secured to the outlet end of the casting. The flame tubes are located with their mouths substantially in the plane of the outlet end of the casting and are supported at their inlet ends by the individual duct parts which engage with the mouths of the flame tubes substantially in the same manner as described in connection with the first embodiment. In this construction, however, each duct part is supported by a single strut-like part which extends radially outwardly from the duct part to be supported from the outer wall of the inlet casting.

In this construction also the strut-like member is extended to within the duct part and terminates at its inner end in a boss supporting the fuel injection device associated with the flame tube and one or more passages are formed in the strut from its outer end to convey fuel to the fuel injection devices.

A third construction of combustion equipment comprises an annular combustion chamber within which is disposed a single annular flame tube, and in this construction there is provided a substantially annular duct part for separating the air which is to flow directly into the flame tube from that which flows into the annular spaces between the flame tube and the walls of the combustion chamber.

The combustion equipment comprises an annular expansion chamber formed with axially and radially-extending strut members connecting the inner and outer walls thereof. The flame tube is formed with its mouth downstream of the strut members, and is

supported at its inlet end by engagement with annularly extending duct parts. These duct parts are supported either directly from said strut members, or the strut members are formed each in two abutting parts one of which parts is formed integral with the expansion chamber walls and the other of which parts is formed integral with a duct part and the duct parts are secured to the expansion chamber through the strut parts. The duct parts are formed with circumferentially-extending " pillar-box " slots which on assembly together define a substantially annular aperture. The duct parts are provided with bearing surfaces, at least on their radially inner and outer peripheral portions, on which the mouth of the flame tube engages. One or more injection nozzles may be associated with each duct part, and said duct parts are divergent in the direction of flow.

Dated this 27th day of June, 1949.

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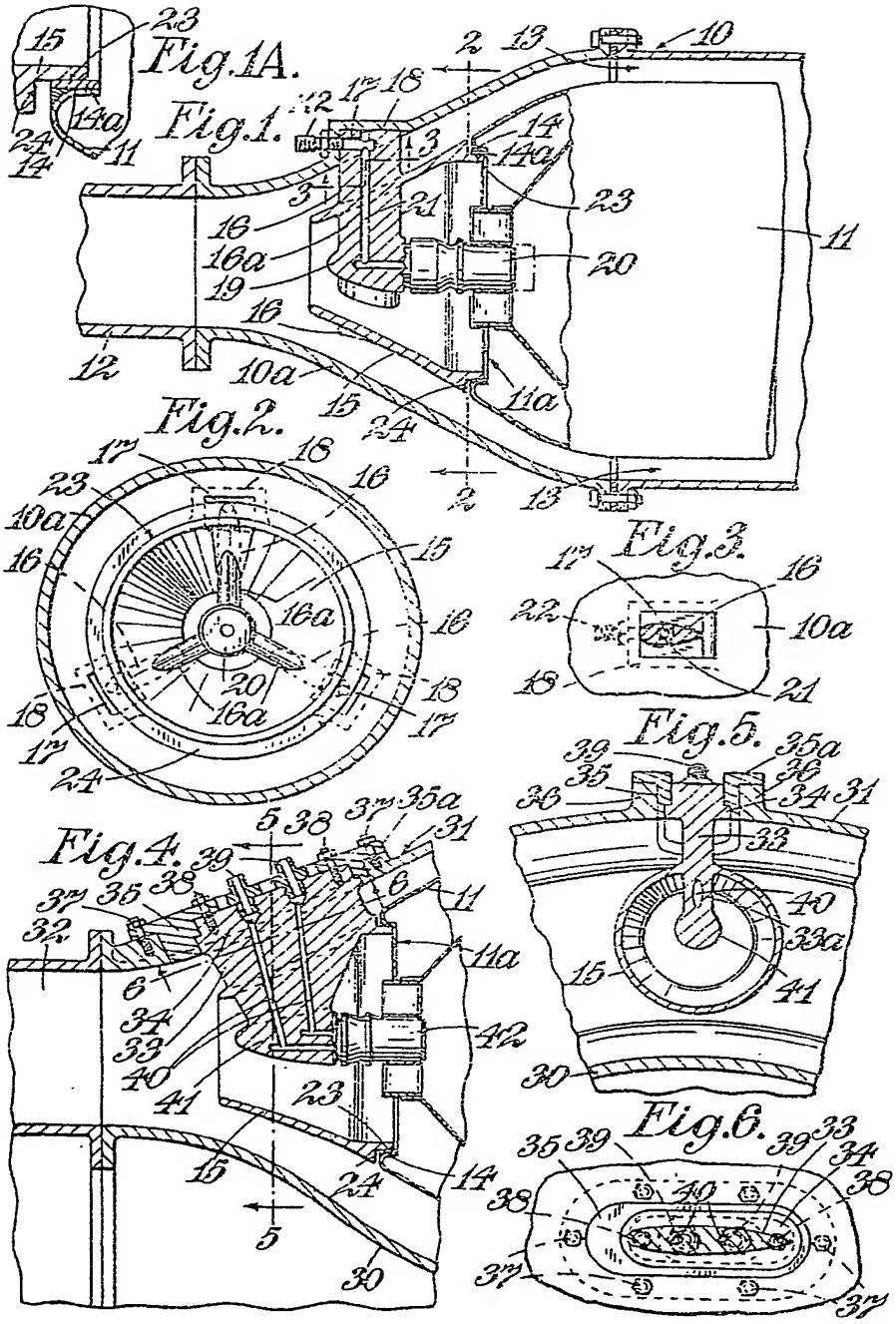

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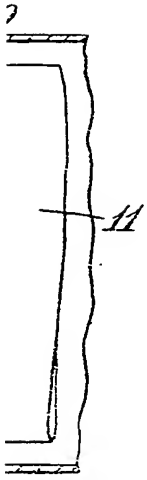


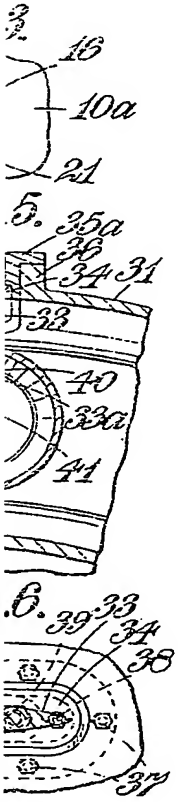


Fig.7.

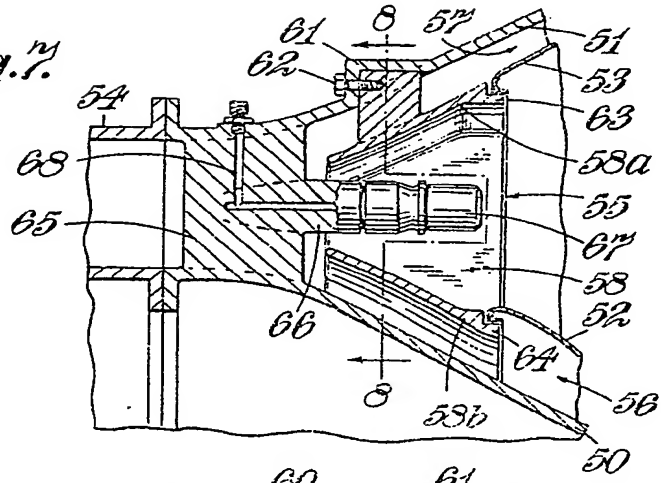


Fig.8.

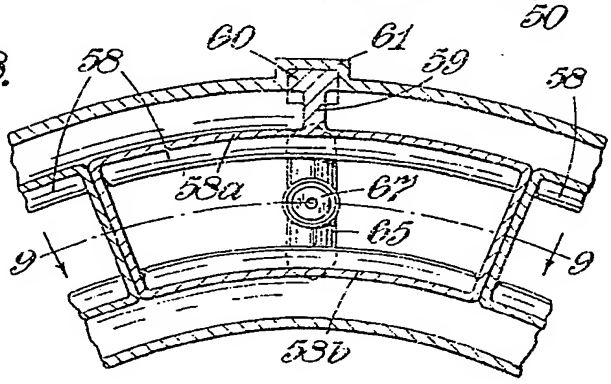
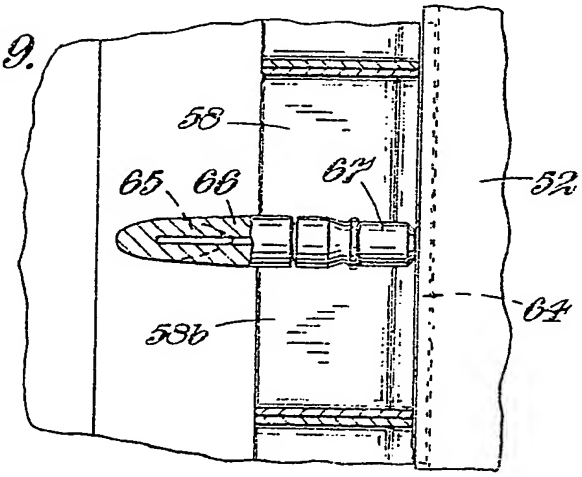


Fig.9.



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